

“On the Geometrical Construction of the Oxygen Absorption Lines Great A, Great B, and α of the Solar Spectrum.”
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In the early part of August, 1890, the photographic work of the normal solar spectrum which I had undertaken had been carried as far as great A, or the limit of visibility in the red, and to $\lambda 8350$, or beyond z , in the invisible regions.

During the two previous months of continuously dull weather, while classifying and comparing results, I was interested, on making a close examination of the head portion of the A line, to find the symmetrical construction, the rhythmical grouping, the harmonic order of sequence, and other characteristics of the B line repeated here in every detail.

These two bands, together with alpha, are composed of a number of doublets or pairs, which approach each other on the more refrangible side with uninterrupted regularity, finally crossing, and at the limiting edges of all three bands the three last pairs overlap each other.

The differences of wave-length between the components of pairs increase in the same order.

These and other properties, which will be referred to, are still more obvious in the trains or flutings.

From its holding an intermediate rank in each of its distinguishing characters I was induced to adopt B as a typical group in a geometrical representation, and to investigate the subject by means of rectangular co-ordinates.

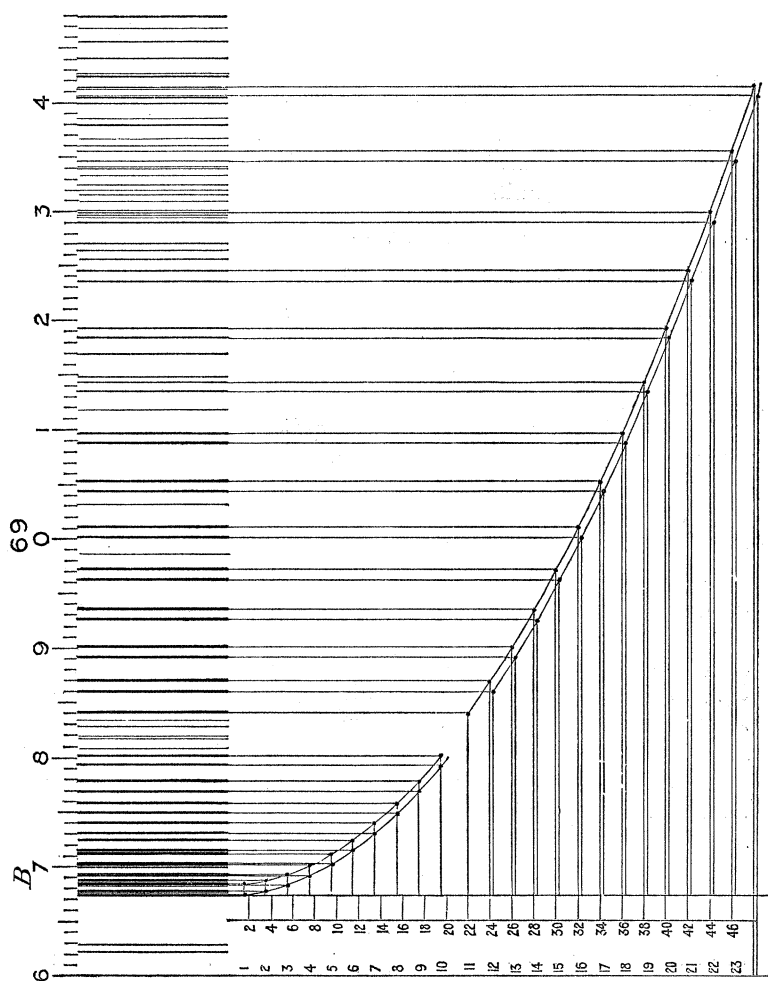
Before a complete analysis could be made out, a micrometer had to be completed. This consisted of a platform, serving as a plate holder, which was made to travel on runners between parallel ways by means of a screw of such a pitch as to move the negative from one division of the scale to the next, for one revolution of the divided plate on the screw head, this latter being divided into 100 parts.

On and over the platform, a microscope is mounted with slide motions at right angles to each other; an index of glass fibre and reflector complete the apparatus.

Over 1000 measurements of nearly 200 lines have been made, 100 of which belong to great A.

In the analysis the axis of x is assumed to occupy a position coincident with, or parallel to, the scale of $1/10^{10}$ m. units, and the positions of the various lines are set off on this scale (see fig. 1) for

FIG. 1.



the group, which is divided into four series. Ordinates are then drawn in the position occupied by each line. The axis of y is divided into a number of equal parts, 1, 2, 3, n . Lines parallel to the axis of x , drawn from each of these divisions, intersect the respective ordinates. The continuous curve passing through the points of intersection is found to possess all the properties of a parabola.

Three points at least are selected to determine the position of the vertex and value of latus rectum. The distance from the origin along y is also found for an ordinate to the first line of a series.

Now, from the equation to the parabola $y^2 = px$, the formula $\lambda = V + \frac{(n+c)^2}{p}$ is derived, where V = the wave-length in $1/10^{10}$ m. units of a point in the spectrum coinciding with the vertex of the curve; p , the latus rectum; n , any number of units, reckoning from the origin; c , a constant.

In practice a representation more suitable for lantern projection being desirable, two units are taken on y for each line of the series; the equation then becomes $\lambda = V + \frac{(2n+c)^2}{L}$, where $L = 4p$, and c has twice its former value.

The computed places in the tables are derived from the equation in the latter form; the maximum want of agreement between these and the observed positions not exceeding (for α and B) 0.015 tenth-metre.

In the case of A the agreement is not quite so close, the maximum difference being about 0.05 tenth-metre.

It might be supposed that the greater difference arose from uncertainties of observation, caused by the greater haziness and breadth of the lines composing the A group; but it so happens that each component is in itself so much of a double as to show a bright rift in the centre, which facilitates the centralisation in some degree.

The differences referred to are attributable to the fact that the curve for any series in A, B, or α is not rigorously parabolic, but one which cuts the parabola in three points, similar to the curve of sines, cutting a straight line and terminating in the same phase as at the origin. This difference is so extremely minute in B (and in α still less) that it would require a representation more than 10 feet square, or a good sized lantern screen, to show two separate tracings at a point of maximum divergence, assuming the tracings to have but a breadth of $1/100$ th of an inch.

Following the stronger doublets in the fluting or train of A on the less refrangible side, is a secondary train of thinner, sharply defined, doublets, which, with a solar altitude of about 10° , may be traced on the photographic prints to about the 12th position. This series, which was not previously known to exist, conforms to the same formula, and in the table of wave-lengths is denominated the "Secondary Train of A." This secondary train follows in the wake of the right component of the primary series. In the head, however, similar secondary groups follow in the wake of both right and left components, overlapping and interlacing each other in such a manner that their resolution into series can only be arrived at by deductive processes; the difficulty is increased by the fact that a large number of positions are occupied by the dense lines of the main band.

These two series will be referred to as "Sub-groups" in the head

of A. They are, with two or three exceptions, given in a fragmentary state. At the same time, there is nothing to prevent their hypothetical positions being carried further, except that the greater density of the principal series precludes the possibility of obtaining any check in regard to their conformity.

Generally, a couple of numbers of the head bands are common to two separate series; this arises from their complexity being suggested by the nature of the analysis, and, as a matter of fact, some of these have been observed as doubles by Professor Rowland, of Baltimore.

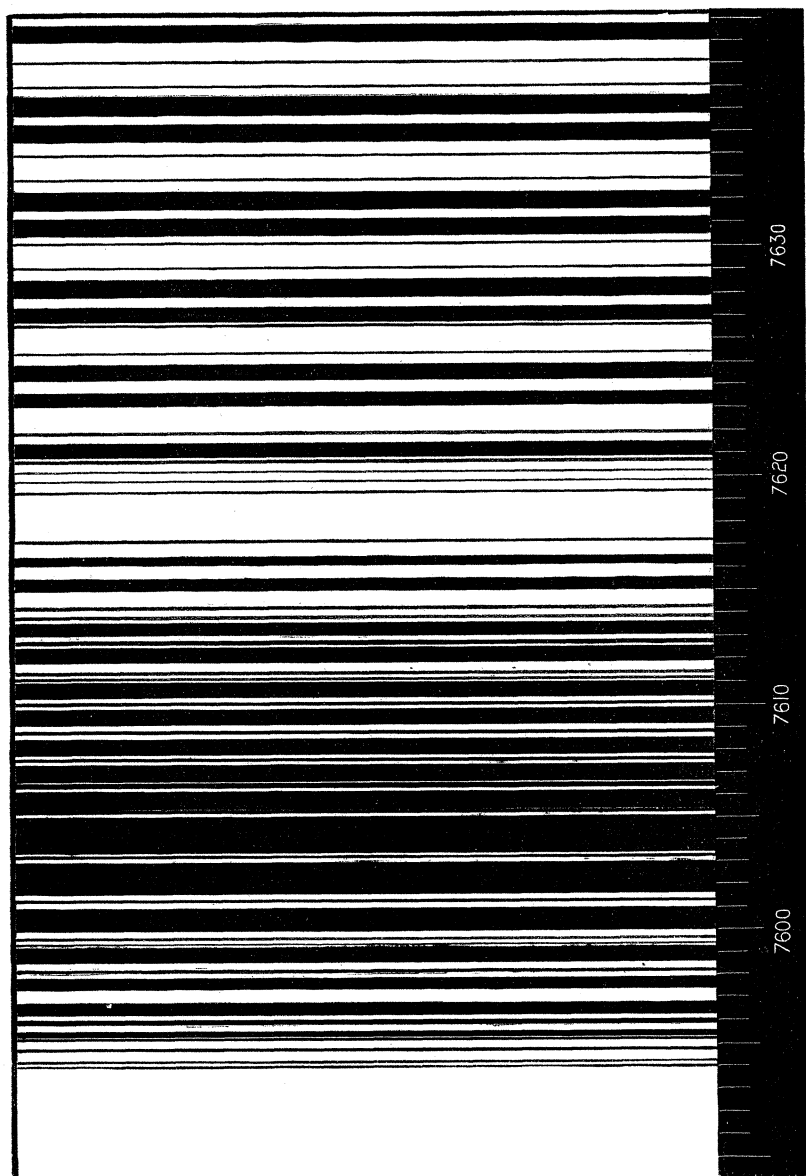
In all cases of this kind a greater density is observable on the prints, and is doubtless the cause of the extra density of 7608·83, which belongs to two sub-groups; the line 7610·10 is known to be a double, but cannot with safety be measured as such.

Owing to their incompleteness, the elements of the curves for the sub-groups in head of A have not been made out, but a glance at their second differences is sufficient to establish their agreement with the preceding form, since an interval is equal to $d' + (n-1)d''$, where d' and d'' are first and second differences, and n any interval from the commencement of the series.

Note.—Since writing the above I find that Mr. Johnstone Stoney has written a note which was published with a paper by Dr. Huggins on the spectrum of hydrogen, in which he refers to the conditions under which members of a harmonic series might fall near to, but not on, a curve.

Fig. 2 is an enlargement of part of A

FIG. 2.



Head of the Alpha Line.

1st Series.		2nd Series.	
Computed.	Measured.	Measured.	Computed.
1. 6276·792	6276·798	6277·652	6277·644
2. 77·020	77·013	77·845	77·856
3. 77·514	77·518	78·190 }	78·335
4. 78·275	78·190 }	78·280 }	
	78·280 }	78·370 }	
	78·370 }	79·084	79·082
5. 79·302	79·302	80·095	80·095
6. 80·596	80·594	81·374	81·375
7. 82·156	82·148	82·924	82·922
8. 83·983	83·990	84·735	84·736
V = 6276·775		V = 6277·632	
L = 30·019		L = 29·964	
c = -1·29		c = -1·41	

Train of the Alpha Line.

1st Series.		2nd Series.	
Computed.	Measured.	Measured.	Computed.
9.	6287·935	6287·942
10. 6289·596	6289·591	90·411	90·408
11. 92·344	92·350	93·140	93·141
12. 95·356	95·360	96·141	96·140
13. 98·634	98·640	99·416	99·407
14. 6302·176	6302·178	6302·941	6302·940
15. 05·984	05·980	06·741	06·740
16. 10·056	10·040	10·795	10·806
17. 14·394	14·399	15·135	15·140
18. 18·996	19·008	19·750	19·740
V = 6276·693		V = 6277·746	
L = 30·19		L = 29·985	
c = -0·263		c = -0·515	

Head of Great B.

1st Series.		2nd Series.	
Computed.	Measured.	Measured.	Computed.
1. 6867·464	6867·455	6868·457	6868·464
2. 67·776	67·788	68·782	68·771
3. 68·338	68·337	69·330	69·326
4. 69·150	69·148	70·130	70·130
5. 70·212	70·220	71·180	71·182
6. 71·523	71·530	72·485	72·484
7. 73·084	73·080	74·039	74·033
8. 74·895	74·892	75·834	75·831
9. 76·955	76·950	77·879	77·877
10. 79·266	79·274	80·170	80·172
V = 6867·394		V = 6868·397	
L = 32·03		L = 32·194	
c = -0·5		c = -0·53	

Train of Great B.

1st Series.		2nd Series.	
Computed.	Measured.	Measured.	Computed.
11.	6884·077	6884·090
12. 6886·012	6886·000	86·998	86·990
13. 89·181	89·182	90·140	90·142
14. 92·601	92·615	93·560	93·545
15. 96·271	96·277	97·200	97·201
16. 6900·192	6900·193	6901·120	6901·108
17. 04·364	04·368	05·264	05·267
18. 08·786	08·786	09·680	09·678
19. 13·458	13·444	14·334	14·340
20. 18·382	18·367	19·245	19·255
21. 23·555	23·545	24·412	24·421
22. 28·980	28·980	29·840	29·839
23. 34·655	34·662	35·518	35·509
24. 40·580	40·580	41·430	41·431
V = 6867·529		V = 6868·812	
L = 31·922		L = 31·767	
c = +0·29		c = +0·03	

Head of Great A.

1st Series.		2nd Series.	
Computed.	Measured.	Measured.	Computed.
1. 7593·980	7593·98	7595·26	7595·260
2. 94·276	94·28	95·42 } 95·54 } 95·66 }	95·543
3. 94·796	94·79	96·05	96·050
4. 95·540	95·42 } 95·54 } 95·66 }	96·78	96·781
5. 96·508	96·49	97·73	97·736
6. 97·700	97·69	98·90	98·915
7. 99·116	99·12	7600·29	7600·318
8. 7600·756	7600·80	01·96	01·945
9. 02·620	02·64	03·77	03·796
10. 04·708	04·74	05·90	05·871
11. 07·020	07·03	08·21	08·170
12. 09·556	09·54	10·71	10·693
13. 12·316	12·31	13·44	13·440
14. 15·300	15·30	16·39	16·411
V = 7593·904 L = 35·714 c = -0·357		V = 7595·195 L = 35·715 c = -0·473	

Train of Great A.

1st Series.		2nd Series.	
Computed.	Measured.	Measured.	Computed.
15.	7621·260	7621·299
16. 7623·590	7623·535	24·765	24·772
17. 27·310	27·310	28·480	28·480
18. 31·255	31·275	32·445	32·413
19. 35·425	35·460	36·59	36·571
20. 39·820	39·840	40·97	40·954
21. 44·440	44·470	45·57	45·562
22. 49·285	49·305	50·39	50·395
23. 54·355	54·360	55·448	55·453
24. 59·650	59·615	60·715	60·736
25. 65·170	65·148	66·218	66·244
26. 70·915	70·880	71·945	71·977
27. 76·885	76·840	77·89	77·935
28. 83·080	83·025	84·075	84·118
29. 89·500	89·450	90·49	90·526
30. 96·145	96·105	97·13	97·159
31. 7703·015	7703·020	7704·02	04·017
32. 10·110	10·160	11·16	11·100
V = 7594·669 L = 35·556 c = +0·067		V = 7596·044 L = 35·556 c = -0·04	

Secondary Train of Great A.

1st Series.		2nd Series.	
Computed.	Measured.	Measured.	Computed.
15. 7622·076	7622·06	..	7623·290
16. 25·613	25·62	7626·79	26·790
17. 29·356	29·36	30·50	30·502
18. 33·305	39·29	34·42	34·426
19. 37·460	37·46	38·57	38·560
20. 41·821	41·81	42·91	42·910
21. 46·388	46·36	47·46	47·470
22. 51·161	51·19	52·24	52·242
23. 56·140	56·14	57·23	57·226
V = 7593·4535		V = 7596·122	
L = 38·835		L = 37·736	
c = +3·34		c = +2·019	

Sub-group in Head of A following
the 1st Series.

Fragment of Sub-group in Head
of A following the 2nd Series.

Measurements only.		Measurements only.	
Sub-series No. 1.	Sub-series No. 2.	Sub-series No. 3.	Sub-series No. 4.
5. 7597·00	7598·20*		
6. 98·29	99·45		
7. 99·74	7600·90*		
8. 7601·42	02·57*		
9. 03·25	04·40		
10. 05·36	06·48	10. 7606·48	
11. 07·65	08·83	11. 08·83	7610·10 <i>d</i>
12. 10·10 <i>d</i>	11·28	12. 11·45	
13. 12·84	13·98	13. 14·28	
14. 15·78	..	14. 17·25 ?	

The numbers marked with an * are hypothetical positions.

FIG. 2.

